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LONG LIFE 80Ah STANDARD IPV NiH2 BATTERY CELL

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SUMMARY

A standard Nickel-Hydrogen (NiH2) Individual Pressure Vessel (IPV) battery cell is needed to meet future low cost, high performance mission requirements for NASA, military, and civil space programs. A common or standard cell design has evolved from the heritage of HST, Milstar and other Air Force Mantech cell designs with substantial flight experience, while incorporating some of the historical COMSAT cell design features described in Reference (1). Key features include slurry process nickel electrodes having high strength, long life and high yield (lower cost), and dual layer Zircar separators for improved KOH retention, uniformity and longer life. The cell design will have a zirconium oxide wall wick inside the pressure vessel to redistribute electrolyte and extend life. The slurry electrode will be 35 mils thick to take advantage of qualified cell mechanical configurations and proven assembly and activation techniques developed by Eagle Picher Industries (EPI) for the Hubble Space Telescope (HST) RNH-90-3 and "Generic HST" RNH-90-5 cell designs with back-to-back nickel electrodes produced by the dry sinter process. The 80Ah common cell design can be scaled to meet capacity requirements from 60Ah to 100Ah. Producibility, commonality and long life performance will be enhanced with the robust cell design described herein.

BACKGROUND

The battery cell technology flow shown in Figure 1 summarizes evolution of various battery cell designs at LMSC beginning with the Air Force NiH2 Flight Experiment. This led to development of the RNH-76-3 cell design by EPI. Back-to-back truncated disk slurry aqueous (Bell) process nickel electrodes developed in the 1970s by COMSAT were combined with asbestos separator material for the RNH-76-3 cell design. Back-to-back pineapple slice dry sinter aqueous (Bell) process nickel electrodes were later developed in the 1980s by EPI for HST and Milstar battery applications. These applications utilize Zircar separators in conjunction with cell stack design concepts developed by Hughes Aircraft Corporation and the Air Force, which were later qualified for the HST RNH-90-3, "Generic HST" RNH-90-5 and Milstar RNH-76-11 Mantech cells.

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Performance advantages of the Mantech cell type used by LMSC include lower cell impedance from use of Zircar material in place of asbestos separator used for the COMSAT cell, greater yield in cell build due to decreased sensitivity to electrolyte quantity, and greater energy density due to the high porosity (84%) dry sinter plaque. The COMSAT cell design, using slurry 80% porosity plaque with improved strength properties, has improved plate yield (lower cost) versus the dry sinter plaque cell design. A desire to combine the best characteristics of the COMSAT and Mantech cell configurations has led to the common cell design described herein.

GENERAL CELL DESCRIPTION

The standard cell design described herein has been designated an RNH-90-9 cell by EPI based on similarity to the RNH-90-5 cell design. The design builds upon heritage of HST, Milstar and other Air Force Mantech cell designs with substantial flight experience, while incorporating some of the historical COMSAT cell design features described in Reference (1). The 80Ah NiH_2 battery cell will have 48 slurry process nickel electrodes contained in a 9.0 inch long pressure vessel with a 0.030 inch nominal wall thickness. Key features include slurry process nickel electrodes with 80% porosity for high strength, long life and high yield (lower cost), and dual layer Zircar separators for improved KOH retention, uniformity and longer life. The electrolyte concentration will be 31% KOH in the discharged state for improved low temperature discharge voltage performance. The cell design will have a zirconium oxide wall wick inside the pressure vessel to redestribute electrolyte and extend life. While LMSC has chosen a 48-electrode version of the common cell to avoid mechanical requalification, this design could be easily scaled to meet capacity requirements from 60Ah to 100Ah. The slurry electrodes will be 35 mils thick to take advantage of qualified Mantech cell mechanical configurations, and proven assembly and activation techniques identified in Reference (2) for the HST RNH-90-3 cell design with back-to-back nickel electrodes produced by the dry sinter process. The common cell design will have 5/16 inch terminals and four electrode tab thicknesses of 5, 7, 9 and 11 mils for lower cell impedance at discharge rates greater than 40A. The cell will weigh approximately 2072g and have a rating of 80Ah at a 40A (C/2) discharge rate to 1.10V/cell (24.2V/Battery) following a standard charge at 0°C. Nickel precharge in the range from 15% to 20% should result in a maximum expected operating pressure (MEOP) of 1075 psi at beginning of life (BOL) for this cell design. It has been demonstrated that pressure vessels made with 0.030 inch base Inconel 718 material provide a nominal safety margin of 3X for an MEOP of 1100 psi on RNH-76-3 cells.

The common cell is not optimized for minimum weight for BOL capacity performance, however, in theory, stronger plate material should have longer life under similar operating conditions. This would allow greater DOD operation for the common cell in both geosynchronous and low earth orbit (LEO) applications which should minimize or eliminate the weight penalty. Test data summarized in Reference (3) show operational performance characteristics over the temperature range from -10°C to +20°C for the RNH-90-5 cell design with back-to-back nickel electrodes produced by the dry sinter process. The common cell, designated as RNH-90-9, should have similar electrical performance characteristics as the "Generic HST" RNH-90-5 cell design. The cell would have a rating of 80Ah at a 40A (C/2) discharge rate to 1.10V/cell (24.2V/battery) following a standard charge at 0°C. Testing of the RNH-90-5 cell was accomplished to identify usefulness of the common cell in a generic LEO application. This short term testing identified advantages over the COMSAT cell type which the common cell will replace. Other predicted performance and operating characteristics of the cell are discussed in the following section.

PERFORMANCE PREDICTION

The electrical and thermal performance of an RNH-90-5 cell similar to that used on HST was initially characterized over a matrix of operating conditions from -10°C to +20°C. Testing included standard capacity tests and electrical cycling using 12-hour cycling regimens incorporating constant DOD cycles with step changes in the cell current at three points in the discharge as described in Reference (3). Subsequently, cycling was performed to characterize cell voltage under both constant charge/constant discharge conditions required for a LEO operating environment at +10°C. Four discharge rates (40A, 55A, 75A and 90A) were used in a cyclic scheme which subjected cells to a constant 44 percent DOD each cycle. Because of the relatively high charge rate (38A) required to maintain energy balance for the LEO test, it was necessary to raise the voltage/temperature (V/T) charge termination level to 1.54V/cell (33.9V/battery) to achieve stabilization during the test. Post +10°C capacity testing shows a usable capacity of 70Ah for a recharge ratio of 1.02 to 1.20V/cell (26.4V/battery) at a 40A (C/2) discharge rate. V/T optimization should allow for a greater usable capacity. The discharge scheme for the four distinct cycles was as follows:

Cycle A: 40A for 13.3 min., 75A for 7.1 min.
55A for 9.7 min., 90A for 5.9 min.

Cycle B: 55A for 9.7 min., 90A for 5.9 min.
40A for 13.3 min., 75A for 7.1 min.

Cycle C: 90A for 5.9 min., 40A for 13.3 min.
75A for 7.1 min., 55A for 9.7 min.

Cycle D: 75A for 7.1 min., 55A for 9.7 min.
90A for 5.9 min., 40A for 13.3 min.

Cycles were performed in the order A,B,C,D,A,B,C,D etc. Cycling was repeated until "stability" was reached. Stability is reached when time to charge off for consecutive cycles does not differ by more than 4 minutes and the discharge voltage is stable. Data shown in Attachment 1 summarize test results obtained at the four discharge rates for these operating conditions. These data demonstrate capability of the "Generic HST" RNH-90-5 cell design to operate at a maximum DOD of 44% and meet a peak 80A load for a 22-cell battery over a voltage range from 26.4V to 33.9V at +10°C. It is expected that the standard 80Ah NiH2 battery cell described herein will have similar electrical performance characteristics as the "Generic HST" RNH-90-5 cell.

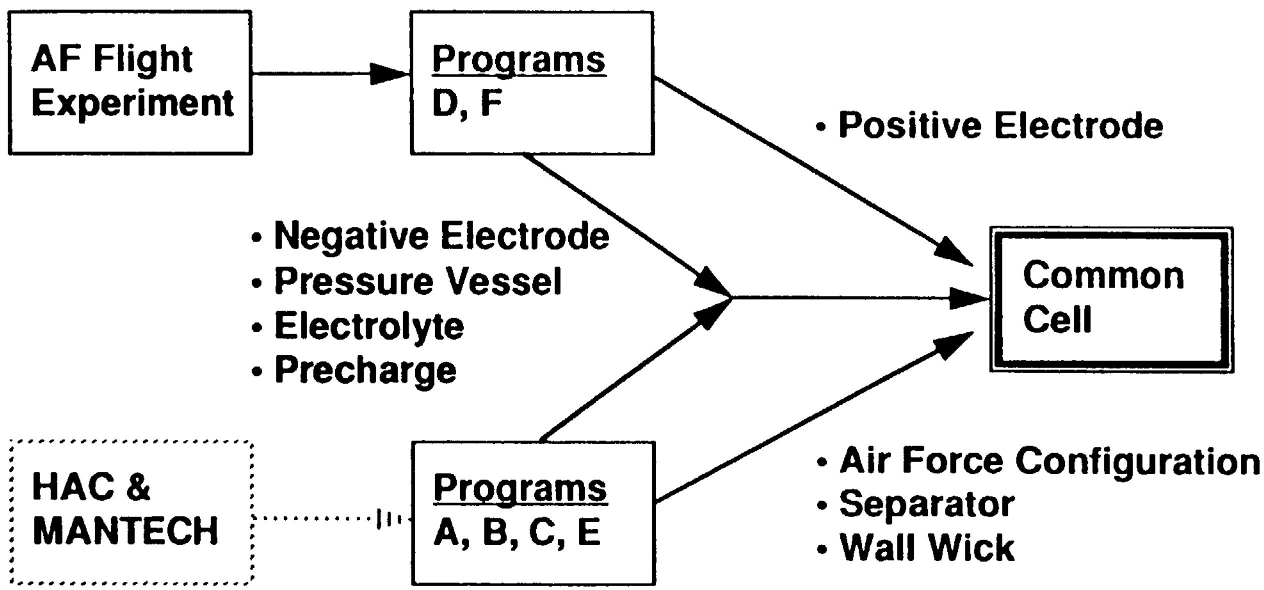
REFERENCES

(1) J. D. Dunlop, G. M. Rao and T. Y. Yi, NASA Handbook for Nickel-Hydrogen Batteries, NASA Reference Publication 1314, September 1993.
(2) D. E. Nawrocki and J. D. Armantrout, "The Hubble Space Telescope Nickel-Hydrogen Battery Design, " 25th IECEC, Reno, NV, August 1990.
(3) J. D. Armantrout and D. P. Hafen, "Performance Characterization of an 80Ah Nickel-Hydrogen Cell," 27th IECEC, Atlanta, GA, August 1993.

ATTACHMENTS

(1) RNH-90-5 Characterization Tests Conducted By Eagle Picher Industries
(2) Presentation Charts

FIGURE 1. CELL TECHNOLOGY FLOW



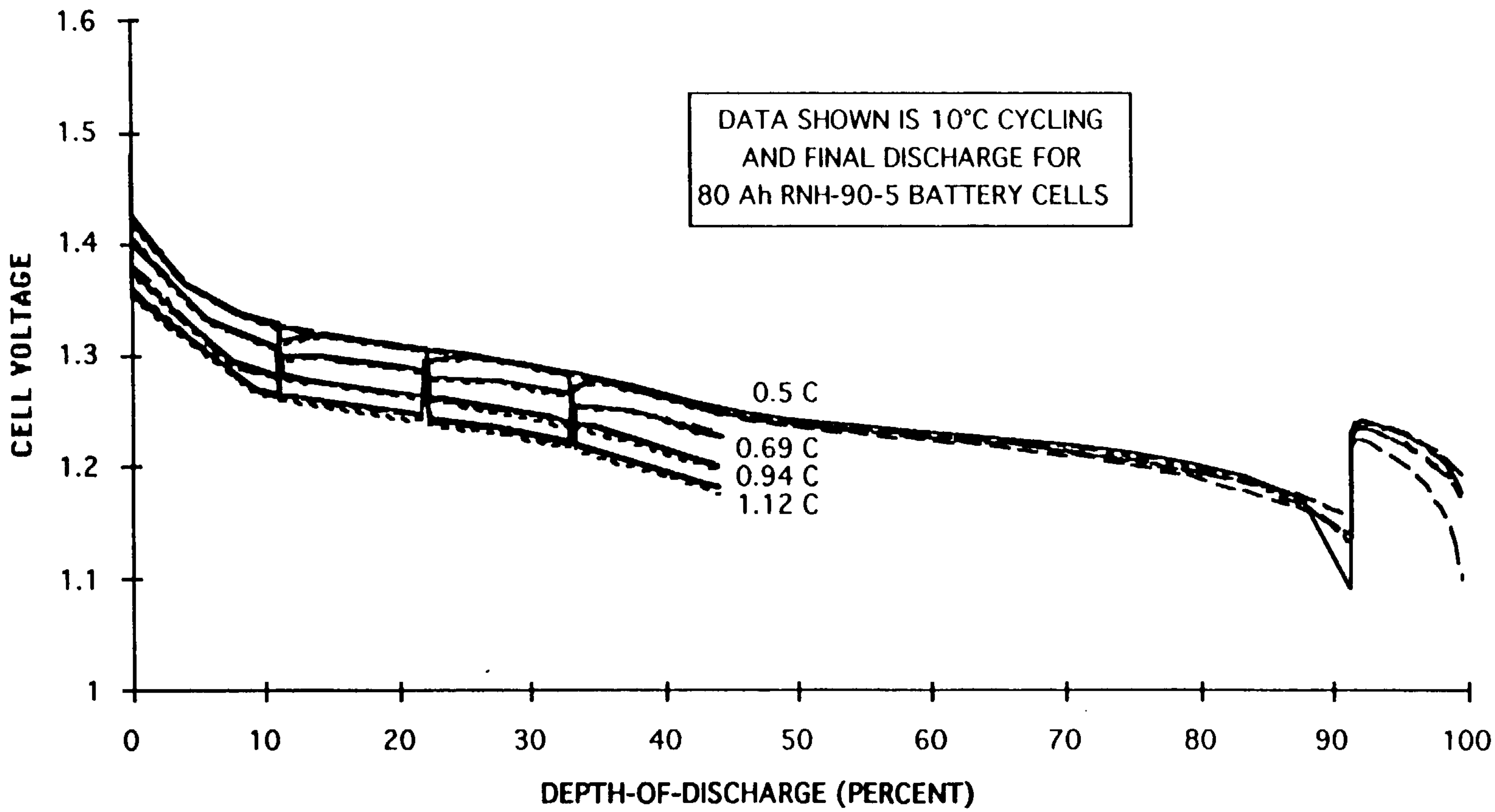
OPTIONS

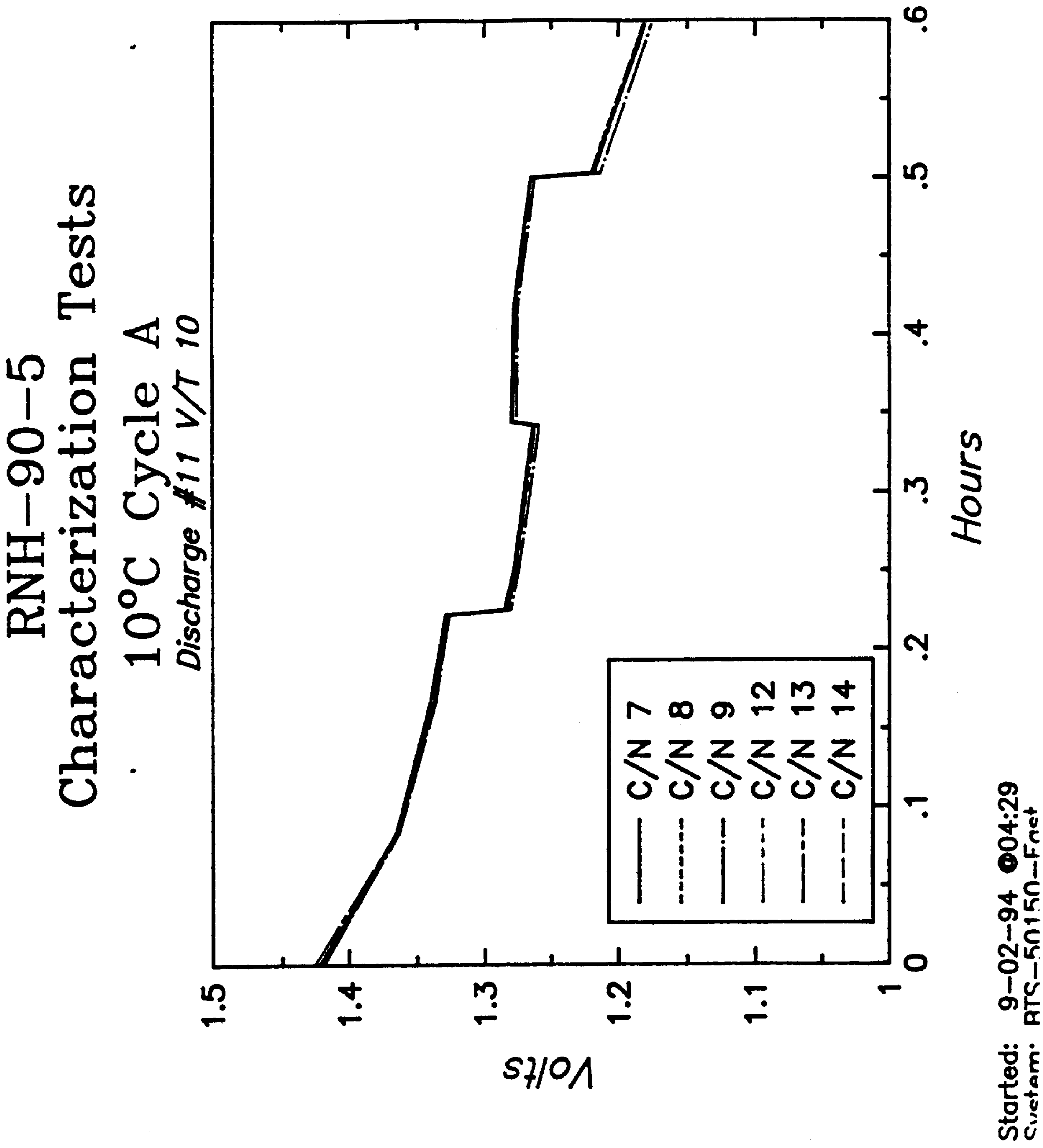
- Electrodes (position and diameter)
- Rated capacity
- Vessel thickness

ATTACHMENT 1.

RNH-90-5 CHARACTERIZATION TESTS
CONDUCTED BY EAGLE PICHER INDUSTRIES

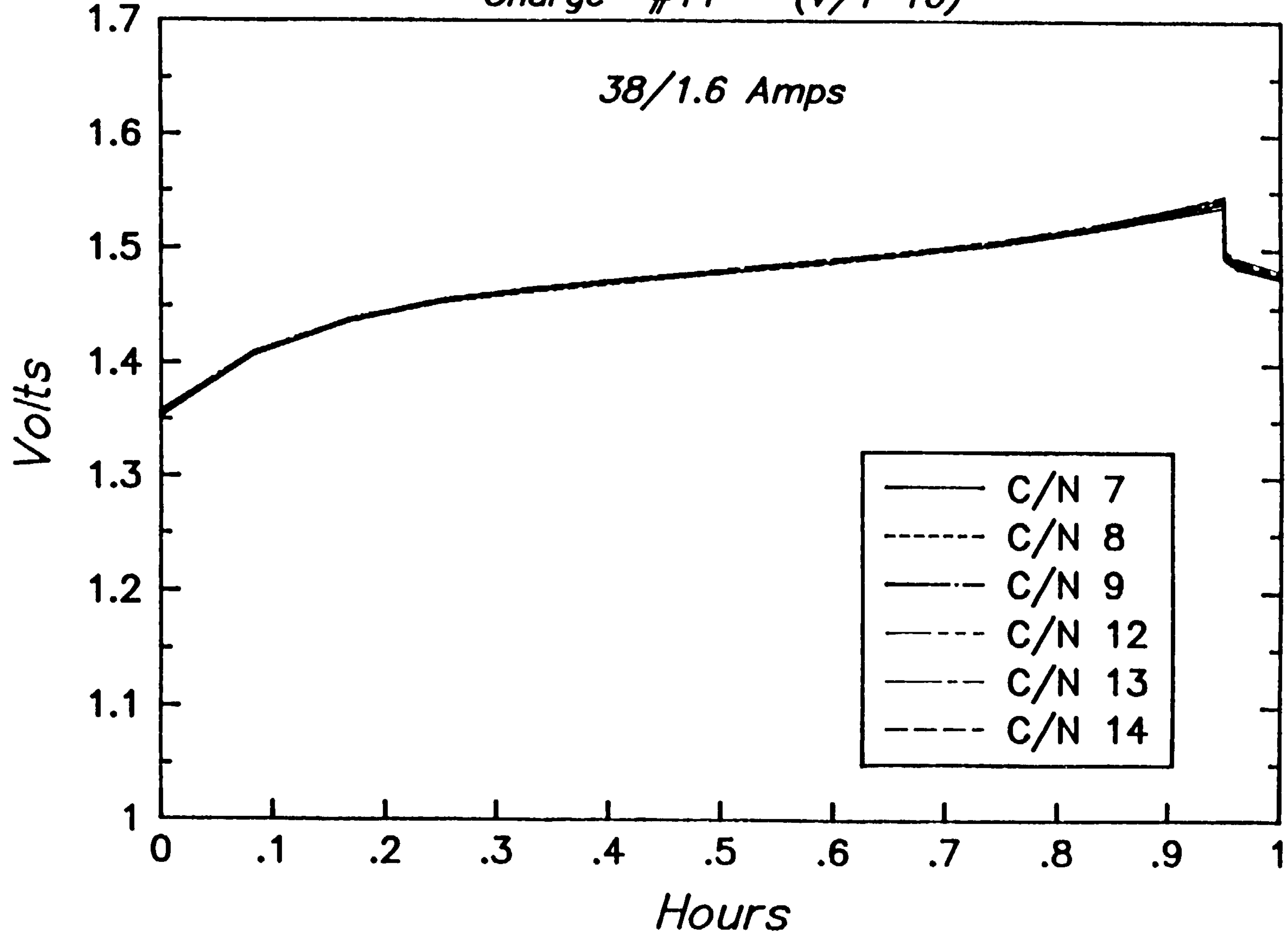
COMMON BATTERY CELL PERFORMANCE




RNH-90-5
Characterization Tests
10°C Cycle A
Discharge #11 V/T 10
Volts
1.5
1.4
1.3
1.2
1.1
1
0
.1
.2
.3
.4
.5
.6
Hours
C/N 7
C/N 8
C/N 9
C/N 12
C/N 13
C/N 14
Started: 9-02-94 @04:29
System: RTS-50150-Fast

RNH-90-5
Characterization Tests
10°C Cycle A

Charge #11 – (V/T 10)



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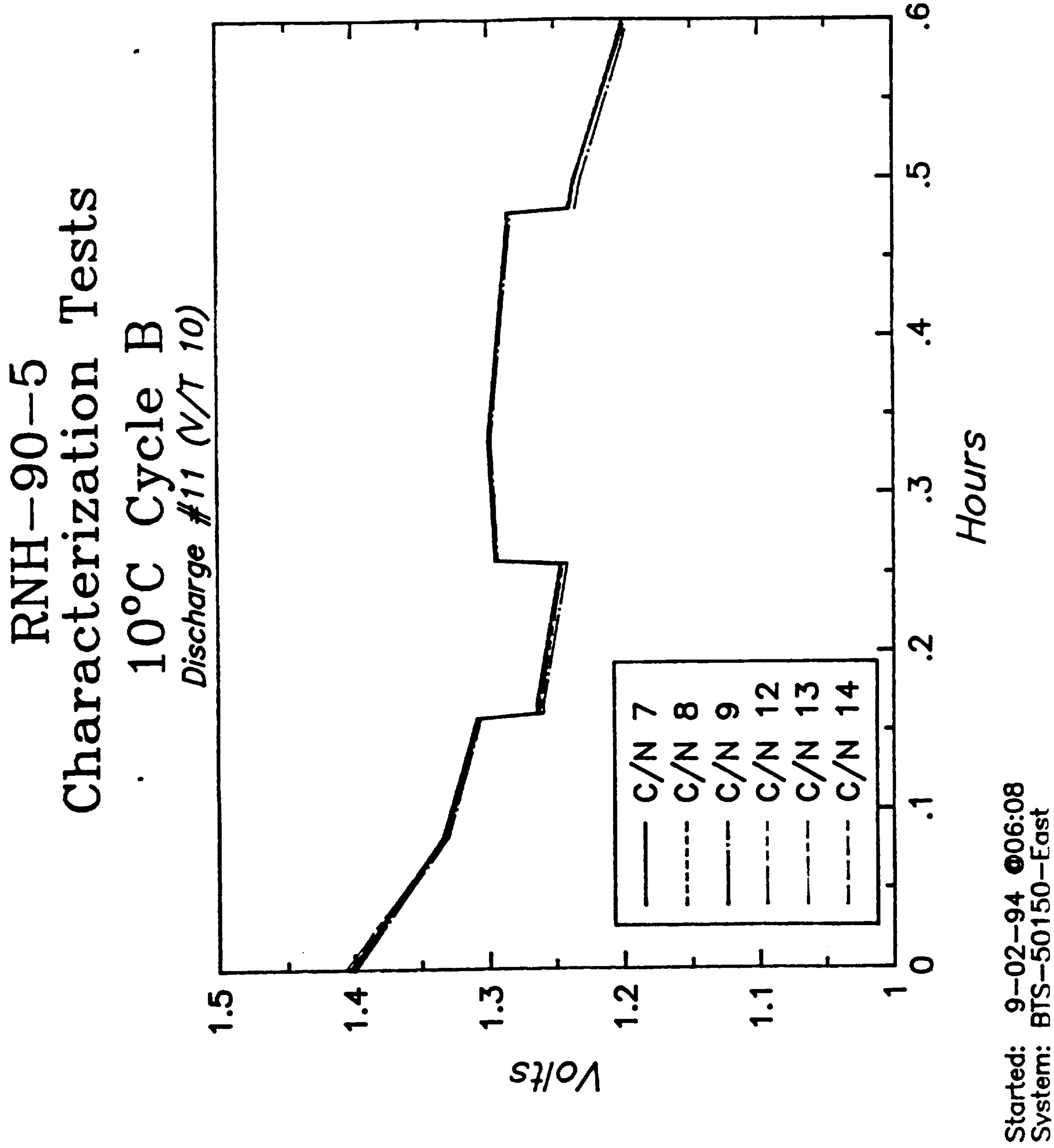
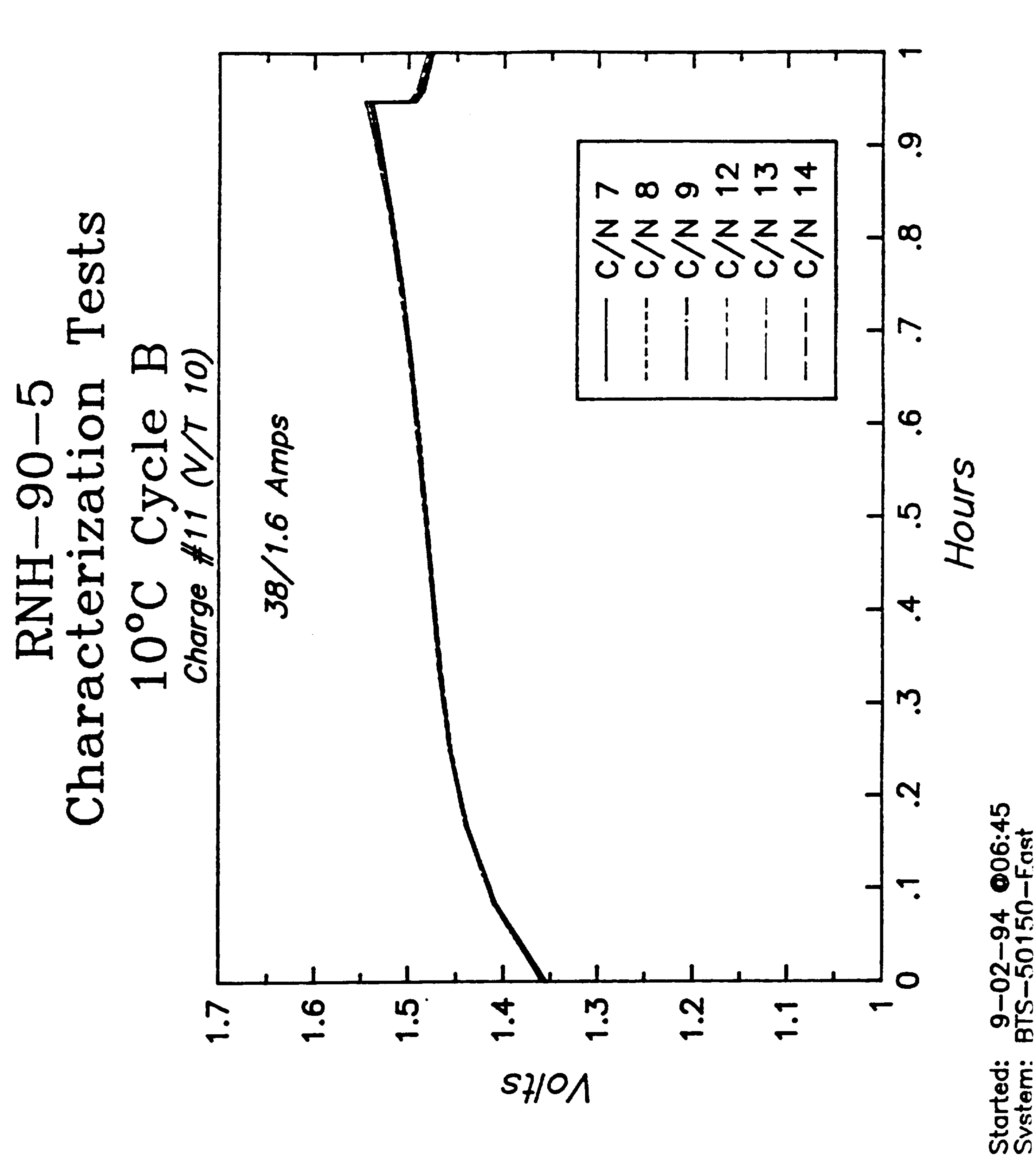
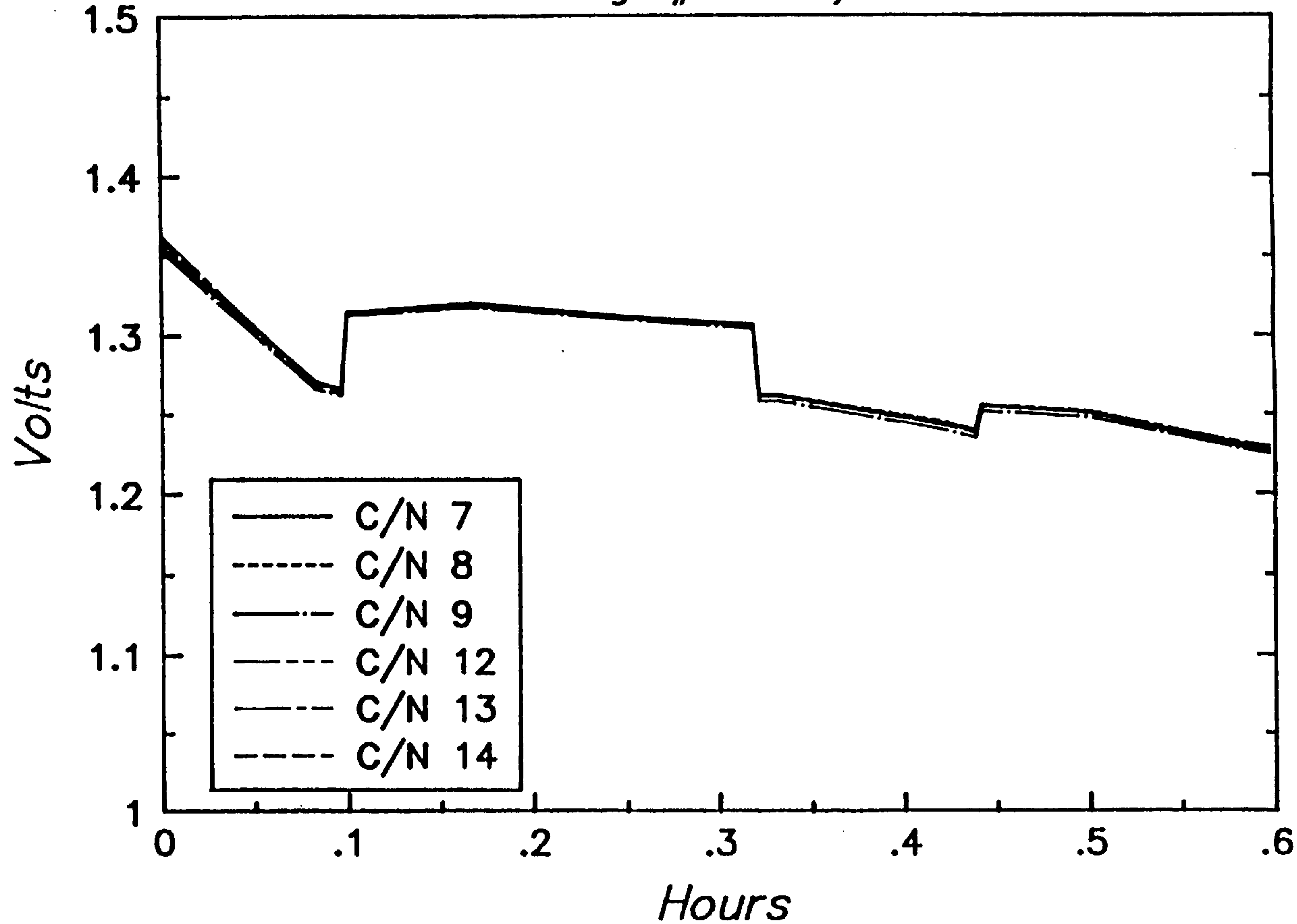


RNH-90-5
Characterization Tests
10°C Cycle B
Discharge #11 (V/T 10)
Volts
1.5
1.4
1.3
1.2
1.1
1
0
.1
.2
.3
.4
.5
.6
Hours
C/N 7
C/N 8
C/N 9
C/N 12
C/N 13
C/N 14
Started: 9-02-94 @06:08
System: BTS-50150-East


RNH-90-5
Characterization Tests
10°C Cycle B
Charge #11 (V/T 10)
38/1.6 Amps
Volts
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
Hours
C/N 7
C/N 8
C/N 9
C/N 12
C/N 13
C/N 14
Started: 9-02-94 @06:45
System: BTS-50150-Fast

RNH-90-5
Characterization Tests
10°C Cycle C
Discharge #11 - V/T 10

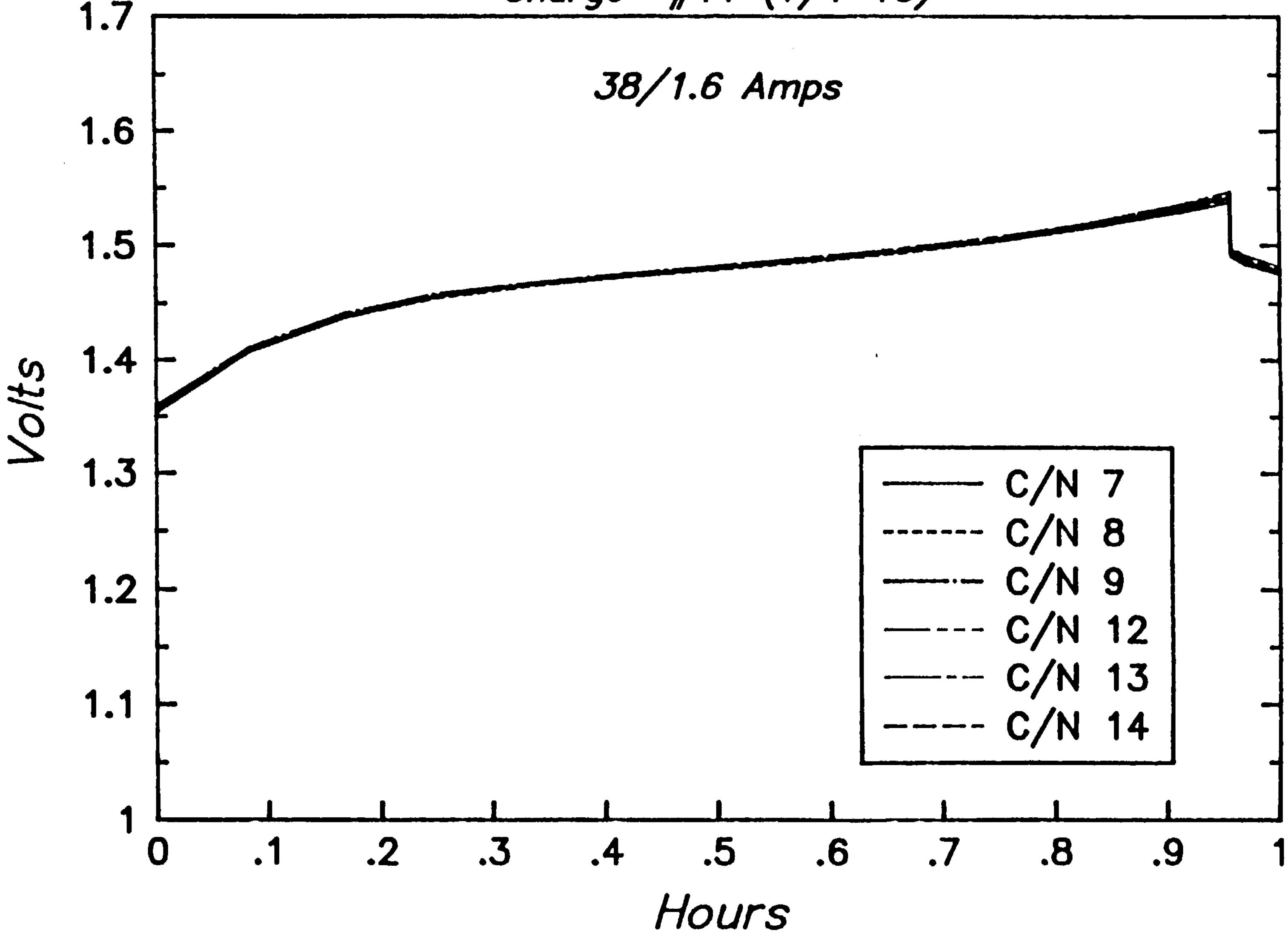


Started: 9-02-94 @07:47
System: RTS-50150-Fast

RNH-90-5 Characterization Tests

10°C Cycle C

Charge #11 (V/T 10)



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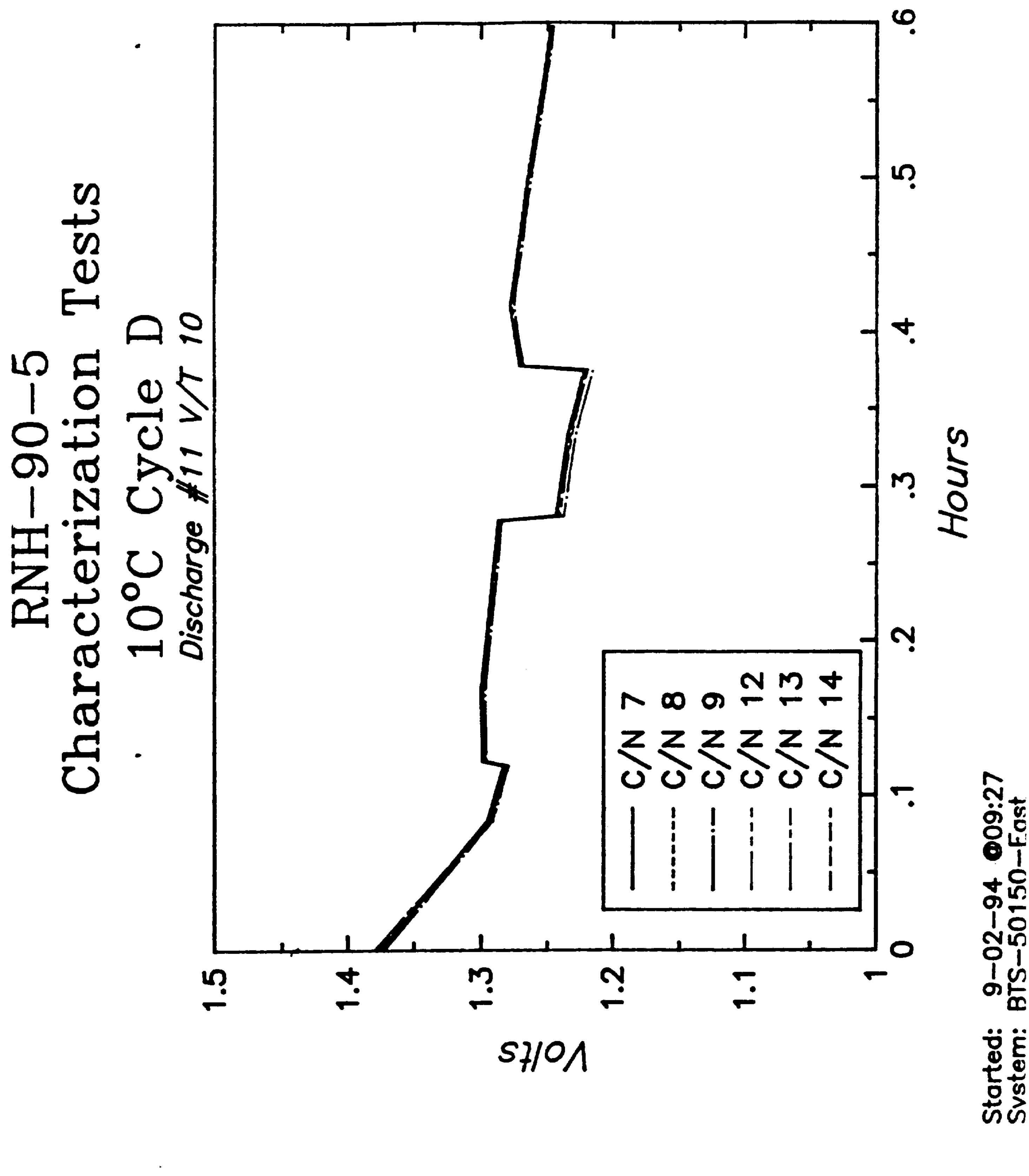
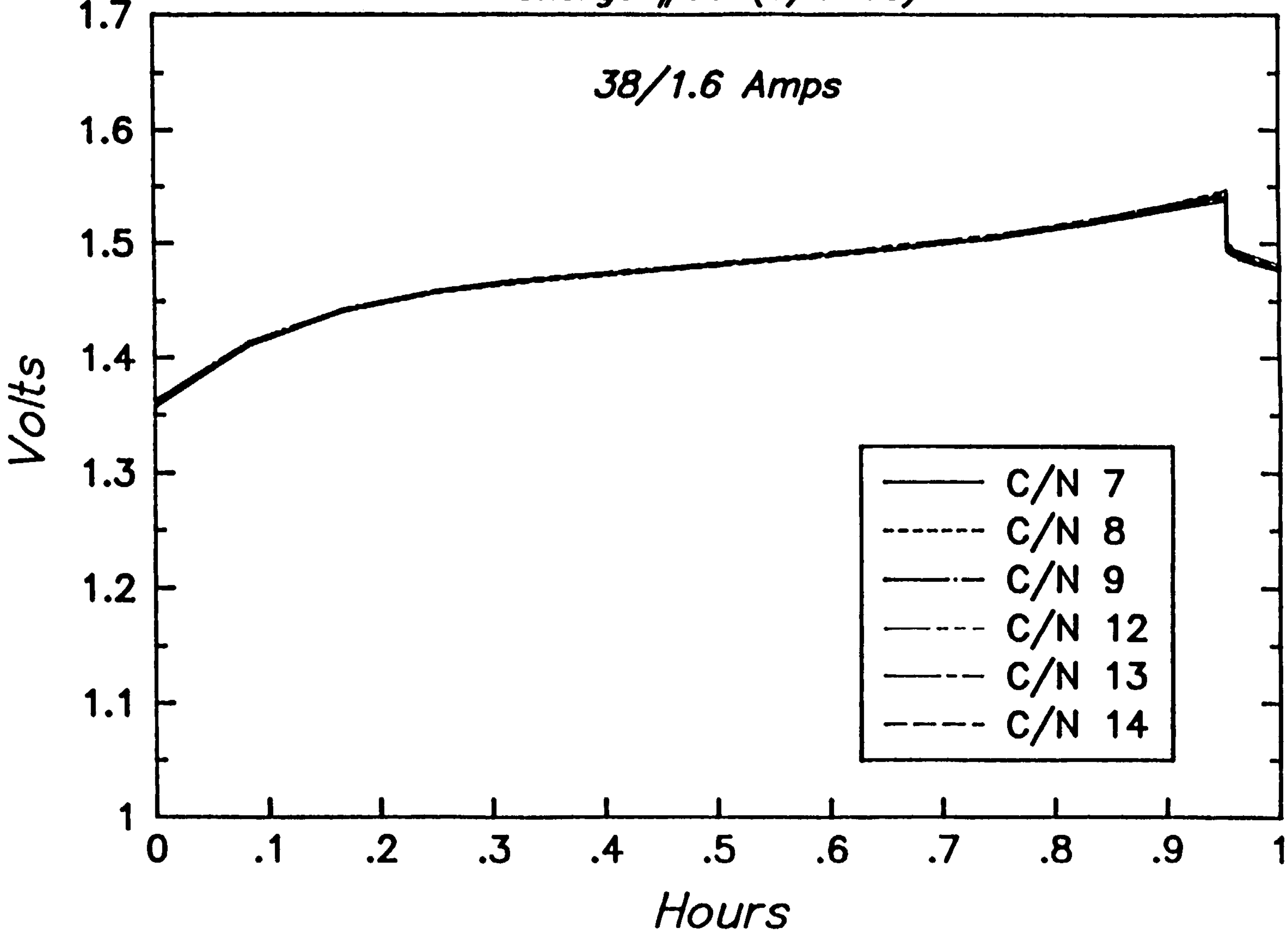
System: RTS-50150-Fast



RNH-90-5
Characterization Tests
10°C Cycle D
Discharge #11 V/T 10
Volts
1.5
1.4
1.3
1.2
1.1
1
0
.1
.2
.3
.4
.5
.6
Hours
C/N 7
C/N 8
C/N 9
C/N 12
C/N 13
C/N 14
Started: 9-02-94 @09:27
System: BTS-50150-East

RNH−90−5
Characterization Tests
10°C Cycle D
Charge #11 (V/T 10)



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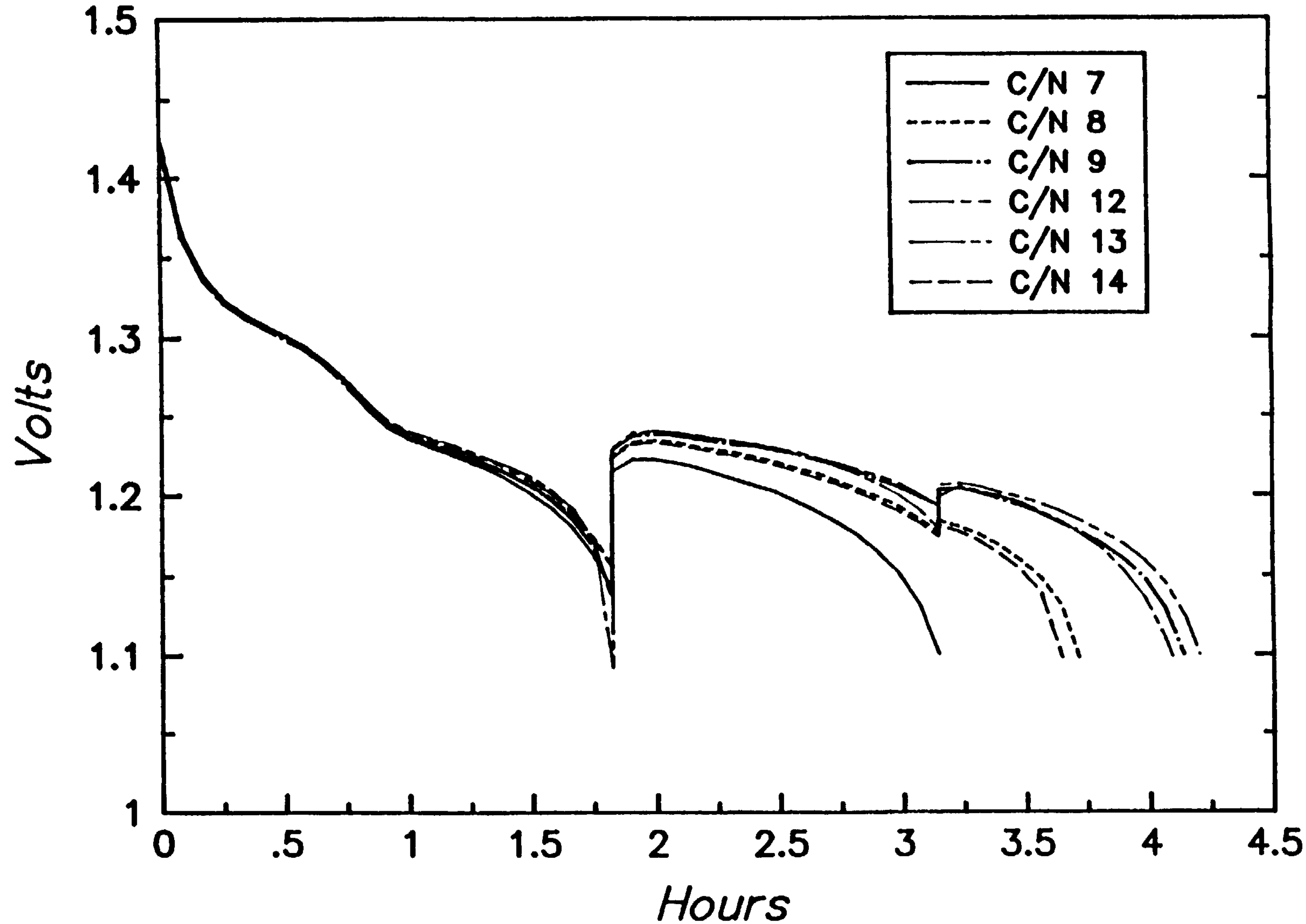
System: BTS−50150−East

RNH-90-5
Characterization Tests
10°C Final Discharge V/T 10



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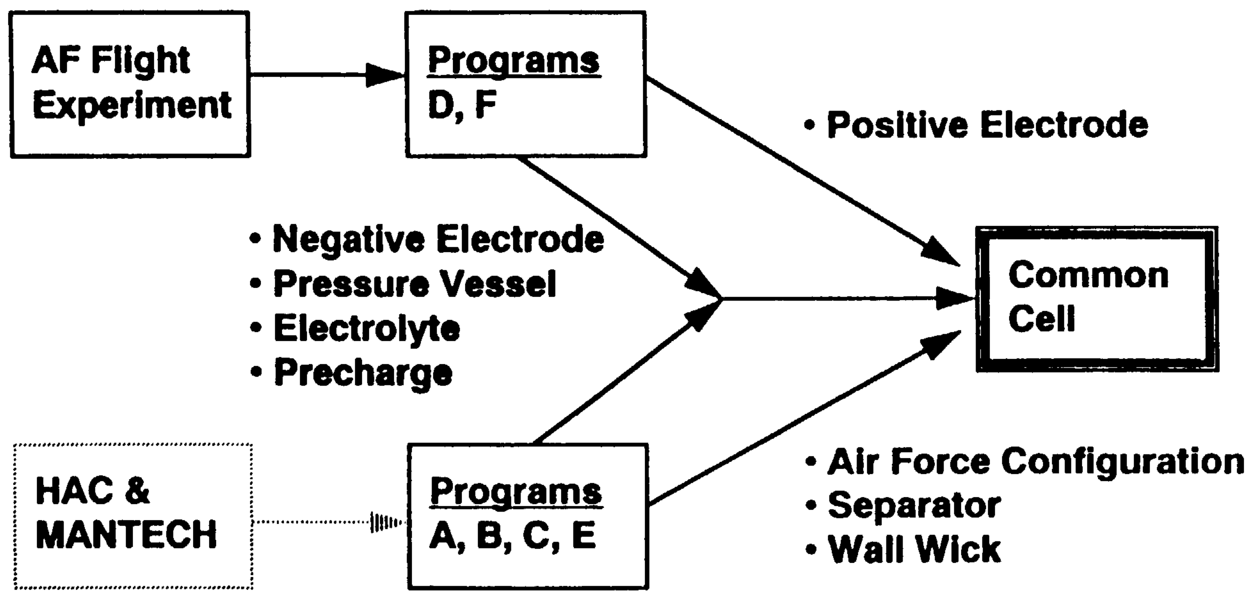
ATTACHMENT 2.

PRESENTATION CHARTS

CELL TECHNOLOGY FLOW



OPTIONS

- Electrodes (position and diameter)
- Rated capacity
- Vessel thickness

LMSC NIH2 BATTERY DESIGN APPLICATIONS

PROGRAM*	CELL TYPE	POSITIVE	SEPARATOR	TERMINAL
A	AF(76AH)	DRY SINTER	ZIRCAR	AXIAL
B	AF(80AH)	DRY SINTER	ZIRCAR	RABBIT
C	AF(88AH)	DRY SINTER	ZIRCAR	RABBIT
D	COMSAT(83AH)	SLURRY	ASBESTOS	RABBIT
E	AF(40AH)	SLURRY	ZIRCAR	RABBIT
F	COMSAT(90AH)	SLURRY	ASBESTOS	RABBIT

*EXCLUDES AF FLIGHT EXPERIMENT NIH2 BATTERY

PRESENT COMSAT ARCHITECTURE

- COMSAT NiH2 CELL ARCHITECTURE SELECTED OVER AIR FORCE (AF) CELL DESIGN IN 1986 DUE TO ACCELERATED GROUND TEST DATA FROM 1970'S AND GEOSYNCHRONOUS EARTH ORBIT (GEO) FLIGHT EXPERIENCE IN THE 1980'S

    - MORE THAN 50,000 LOW EARTH ORBIT (LEO) CYCLES COMPLETED AT 30% DEPTH-OF-DISCHARGE (DOD) ON RNH-30-1 COMSAT CELL DESIGN

    - SIX INTELSAT V COMMERCIAL SATELLITES LAUNCHED BETWEEN 1983 AND 1985 WITH RNH-30-1 BATTERY CELLS OPERATED AT 60% DOD

- TRUNCATED DISK ELECTRODE STACK COMPONENTS WITH TEFLONATED CELL CASE USED IN COMSAT BACK-TO-BACK CELL DESIGN WITH WET SLURRY PLAQUE SINTERING PROCESS AND ASBESTOS SEPARATOR FOR RNH-76-3 CELL

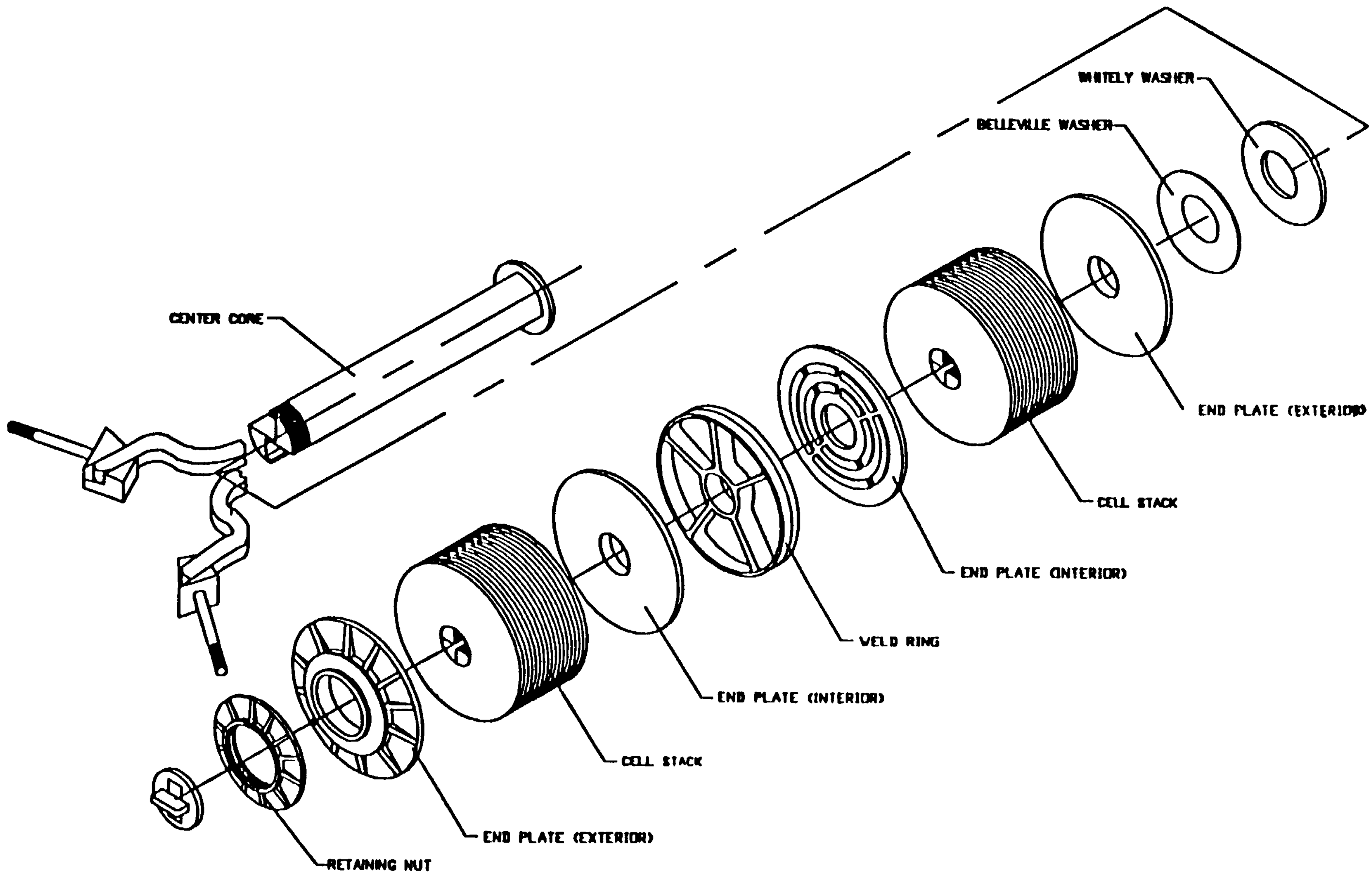
USAF/MANTECH ARCHITECTURE

- HUGHES AIRCRAFT COMPANY (HAC) BEGAN DEVELOPMENT OF NIH2 CELLS FOR LEO APPLICATIONS AT SAME TIME AS COMSAT/INTELSAT DEVELOPMENT EFFORT IN 1970'S
    - AF NIH2 FLIGHT EXPERIMENT LAUNCHED IN 1977
- USAF MANTECH CELL DEVELOPMENT STARTED IN 1981 AT YARDNEY USING COMSAT AND AF DESIGN TECHNOLOGY
- EAGLE-PICHER INDUSTRIES (EPI) MANTECH CELL DESIGN COMBINED TECHNOLOGY FROM COMSAT AND USAF MANTECH DESIGNS FOR MILSTAR AND HST BATTERY CELLS
- ELECTRODE STACK COMPONENTS (PINEAPPLE-SLICE CONFIGURATION) USED IN AF BACK-TO-BACK CELL DESIGN WITH DRY SINTER AQUEOUS PROCESS AND ZIRCAR SEPARATOR MATERIAL FOR "GENERIC HST" RNH-90-5 CELL

LMSC NiH2 COMMON CELL SUMMARY

- SHARED DEVELOPMENT AND PROCUREMENT WILL REDUCE COST AND RISK FOR 80Ah RNH-90-9 CELL DESIGN
- LMSC WILL USE/PROPOSE ON ALL CURRENT HI-POWER NASA AND MILITARY NiH2 BATTERY APPLICATIONS
- STANDARD BATTERY CELL DESIGN FEATURES INCLUDE:
  - SLURRY NICKEL ELECTRODES FOR LONG LIFE AND HIGH YIELD (LOWER COST) BASED ON FLIGHT PROVEN DESIGNS DEVELOPED OVER LAST 20 YEARS
  - DUAL LAYER ZIRCAR SEPARATORS FOR IMPROVED KOH RETENTION, UNIFORMITY AND LONGER LIFE
  - ZIRCONIUM OXIDE WALL WICK TO REDISTRIBUTE ELECTROLYTE AND EXTEND LIFE PERFORMANCE

RNH-90-5 CELL ASSEMBLY CONFIGURATION



POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

Corinne DENNIG and Thierry JAMIN

SAFT ADVANCED BATTERIES
POITIERS FRANCE

CNES
TOULOUSE FRANCE

1994 NASA AEROSPACE BATTERY WORKSHOP
US SPACE AND ROCKET CENTER
HUNTSVILLE AL
NOVEMBER 15-17, 1994

SAFT

POLYAMID SEPARATOR BEHAVIOUR IN NiH_2 CELLS

INTRODUCTION

SINCE 1965, SAFT HAS USED POLYAMID SEPARATORS IN ITS NiCd AND NiH_2 CELLS.

CYCLABILITY OF THIS SEPARATOR IS PROVEN.

OBJECTIVES OF THE STUDY :

- → CLEARLY IDENTIFY MODIFICATIONS OF THE SEPARATOR DURING CYCLING.
- → SHOW THAT THEY HAVE NO IMPACT ON THE CELL CYCLABILITY.

CONTENT :

- → COMPARISON BETWEEN NEW AND AGED SEPARATORS (FROM CELLS WHICH HAVE BEEN CYCLED).
- → COMPARISON BETWEEN SEPARATORS LOCATED IN CONTACT WITH POSITIVE OR NEGATIVE ELECTRODES IN THE CELL.

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

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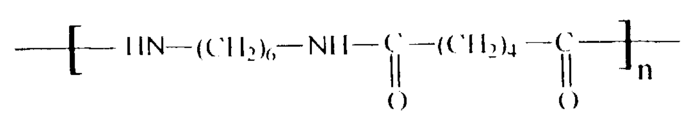
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

1-SEPARATOR CHARACTERISTICS

1.1 - CHEMICAL : FTR 3

FELT : NON WOVEN TISSUE ⟶ MIXTURE OF POLYAMID 6-6 (NYLON 6-6) AND POLYAMID 6

POLYAMID 6-6



1.2 - DIMENSIONNAL :

SPECIFICATION : 0.14 ∓ 0.03 mm (LHOMARGY : micrometer)
DOUBLE LAYER

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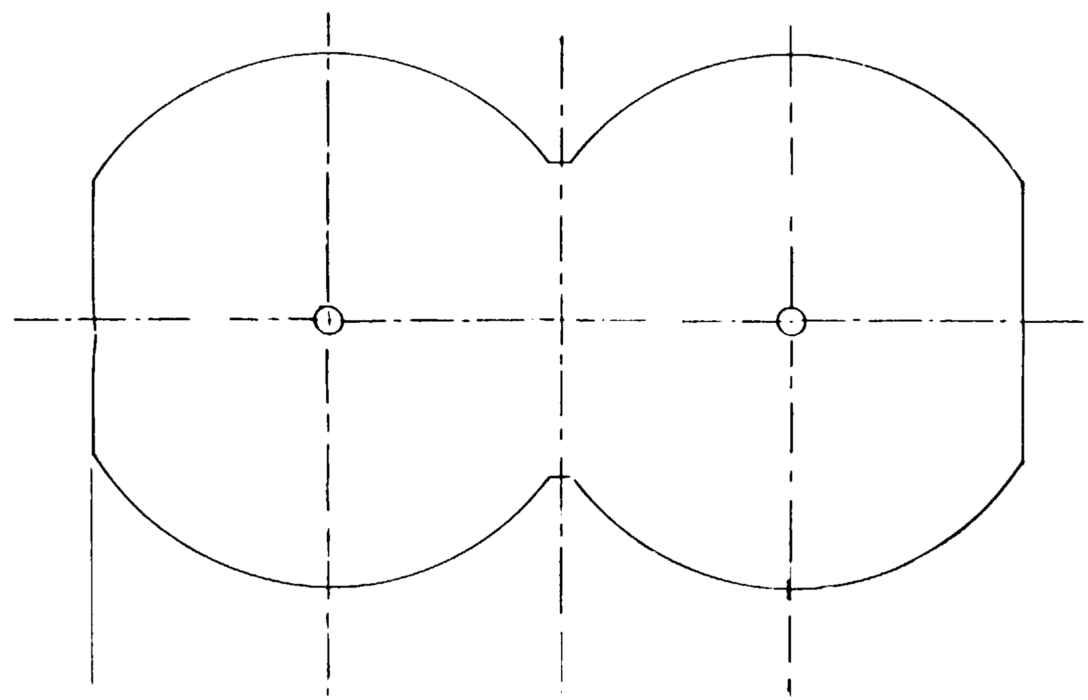
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS



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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

FAILED CELLS FROM TWO CYCLING TESTS WERE USED TO PERFORM THIS STUDY.

2-TYPE OF CYCLING

2.1-TESTS PERFORMED

PARTS OF THESE RESULTS HAVE BEEN PRESENTED LAST YEAR BY Y.BORTHOMIEU AND D.DUQUESNE

GEO

- VHS50BL CYCLING : 20 PERIODS PERFORMED IN ACCELERATED CONDITIONS (T=10°C)

Demonstrate the GEO life cycle with a constant DOD profile (70 %) for 18 GEO seasons
Between season 19th and 20 th : GEO cycle with real 70 % DOD
Reconditionning after each season

LEO

- HRN42 CYCLING BEGUN IN 1985 : 38,000 CYCLES PERFORMED (T=10°C, DOD=40 %) ; TEST still running

Test the suitability of HRN design (electrochemistry) for LEO missions
Compare taper versus cut-off charge management
Test in horizontal position

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

2- TYPE OF CYCLING

2-2 DPA RESULTS

Cell Type	CYCLING	TEST Performer	Number of Cycles completed	Reason of Removal	DPA Observations
VHS50BL n°9	GEO	AE/SP	20 seasons	EOD Voltage below 1 V Low EODV since the beginning of cycling	Ageing of electrochemical components: - drying negative electrode **due to acceptance test deviation :** **H2 leakage on test equipment** No critical ageing of the separator
HRN42 n°5	LEO	ESA	31629	Short circuit	Short due to the positive swelling : **Old design limitation :** **no positive expansion accommodation system** No critical ageing of the separator :

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POLYAMID SEPARATOR BEHAVIOUR IN NiH_2 CELLS

3.1 - SIZE

3.1.1 - THICKNESS

3.1.2 - SURFACIC DENSITY

3.1.3 - APPARENT DENSITY

3.1.4 - CONCLUSION

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

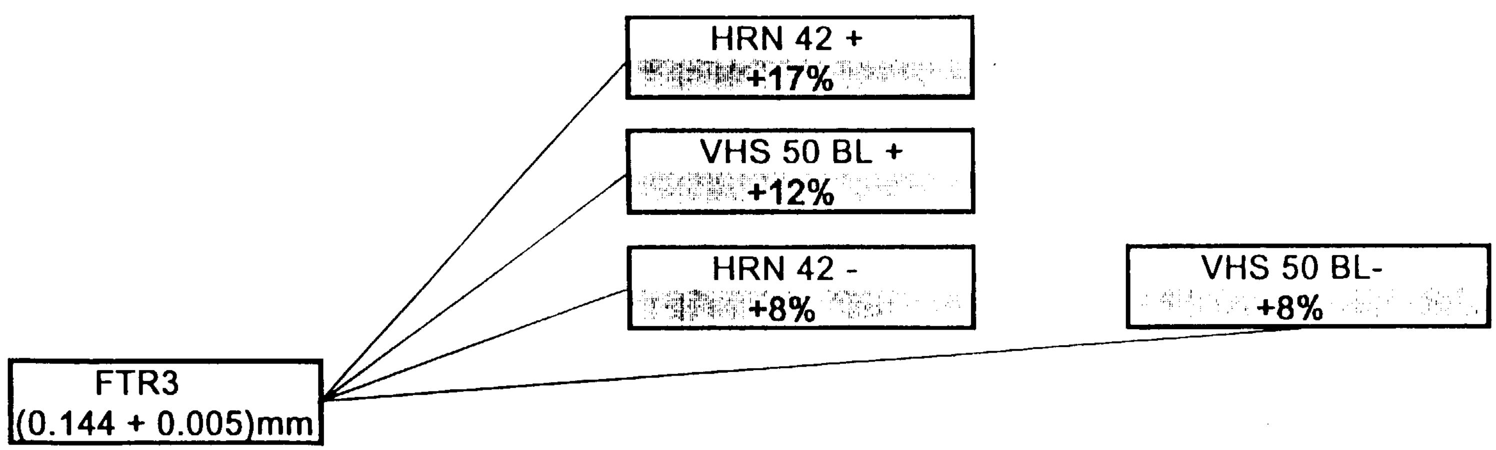
3-SEPARATOR CHARACTERIZATION
3.1-SIZE

3.1.1.- THICKNESS

LHOMARGY MI 20 (electrical micrometer) --> 2 sqcm contact surface, 1 bar pressure service, 4 seconds time lag
SEPARATORS IN A DRY STATE
FOUR MEASUREMENTS FOR EACH SEPARATOR
MEASUREMENTS ON 20 SEPARATORS ABOUT

RESULTS

NEW AGED



NEW SEPARATOR, NEVER IMPREGNATED
NOT AN ABSOLUTE INITIAL REFERENCE

POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.1- SIZE
3.1.1- THICKNESS (CONT'D)

A. SEPARATORS SWELLING

- MODIFICATION OF TEXTURE FIBER DURING CYCLING

B. POSITIVES/NEGATIVES DIFFERENCES

- DUE CERTAINLY TO O2 EVOLUTION DIFFERENCES

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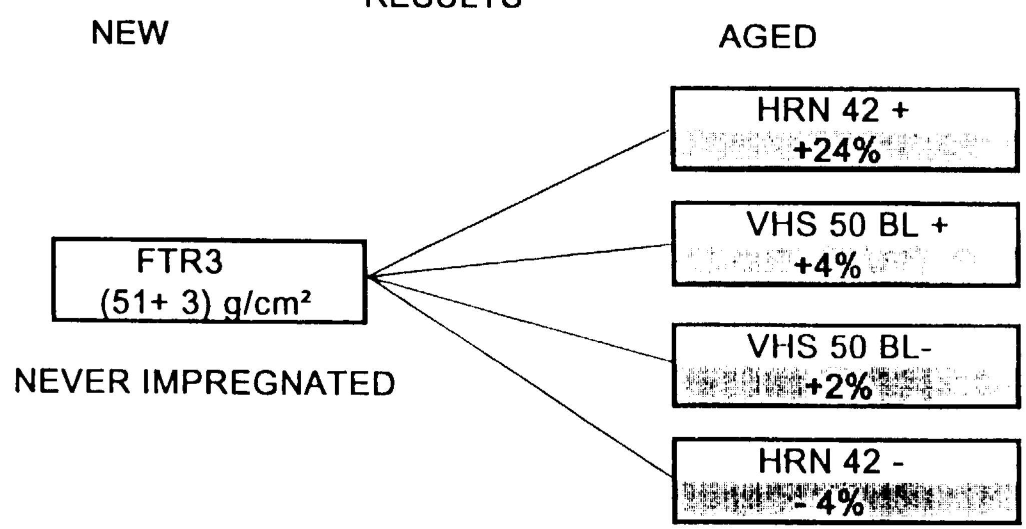
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.1-SIZE (CONT'D)

3.1.2.- SURFACIC DENSITY : WEIGHT PER SURFACE UNIT

SEPARATORS IN A DRY STATE
MEASUREMENTS ON 20 SEPARATORS ABOUT
WEIGHTING ON EACH SEPARATOR (S = 92.5 sqcm)

RESULTS



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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.1- SIZE
3.1.2- SURFACIC DENSITY (CONT'D)

A. TRENDS ARE THE SAME THAN FOR THICKNESS :

- DEPENDS ON NUMBER OF CYCLE

B. HIGHER SURFACIC DENSITY FOR THE POSITIVE SEPARATOR OF HRN 42 CELL

- POSITIVE HYDROXYDE DEPOSIT

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.1 SIZE (CONT'D)

3.1.3.- APPARENT DENSITY : WEIGHT PER VOLUME UNIT

APPARENT DENSITY RO IS LINKED TO SURFACE DENSITY μ AND THICKNESS THROUGH THE RELATION :

$$Rd0 = \mu \times 10/e$$

RESULTS

NEW	AGED
FTR3 350 g/dm3	HRN 42 + : +5%
	VHS 50 BL + & VHS 50BL - : -6%
	HRN 42 - : -11%

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.1.4 CONCLUSION

SEPARATOR MODIFICATIONS WITH CYCLING ARE CHARACTERIZED BY :

- THICKNESS AND SURFACIC DENSITY INCREASE

- HIGHER THICKNESS FOR THE POSITIVE SEPARATOR

REMARK : THE POSITIVE AND NEGATIVE SEPARATORS BEHAVIOUR IS THE SAME FOR ALL LOCATION INSIDE TH CELL.

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3.2 - MECHANICAL CHARACTERISTICS

3.2.1 - MECHANICAL RESISTANCE

3.2.2 - COMPRESSIBILITY MEASUREMENTS

3.2.2.1 - WITH DRY SEPARATORS

3.2.2.2 - WITH KOH ELECTROLYTE

3.2.3 - CONCLUSION

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.2- MECHANICAL CHARACTERISTICS

3.2.1.- MECHANICAL RESISTANCE

TRACTION APPARATUS : LHOMARGY DI 20 (RATE 30 mm/mn, LENGTH BETWEEN JAWS : 110 mm)
DETERMINATION OF THE BREAKING LOAD FOR THE WHOLE SEPARATOR

RESULTS

	SEPARATORS TYPE	STRENGTH (daN)	VARIATION (%)	ELONGATION	VARIATION (%)
NEW SEPARATORS	FTR 3	6.5	/	31	/
	Impregnated FTR 3	6.2	-5	30	-3
AGED SEPARATORS	HRN 42 +	4.1	-37	18.8	-39
	HRN 42 -	3.8	-41.5	20.8	-33
	VHS 50 +	6.6	1.5	23.8	-23.2
	VHS 50 -	7	8	25.6	-17

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.2 MECHANICAL CHARACTERISTICS (CONT'D)

3.2.2.- COMPRESSIBILITY MEASUREMENTS

DRY AND IMPREGNATED SEPARATORS COMPRESSION BETWEEN 0 AND 100 daN

--> THE CELL REPRESENTATIVE STRENGTH IS FROM 10 TO 30 daN

ONE SAMPLE : FIVE SEPARATORS WITH 28.3 sqcm

COMPRESSION SURFACE : 4.9 sqcm

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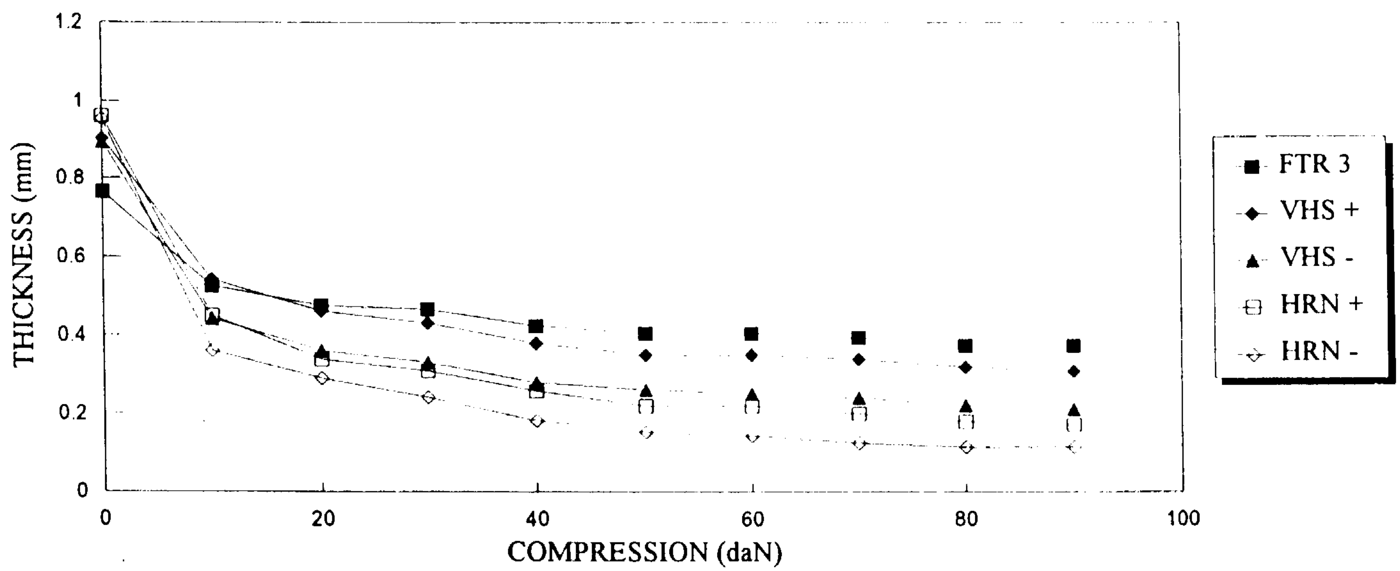
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.2- MECHANICAL CHARACTERISTICS
3.2.2.- COMPRESSIBILITY MEASUREMENTS (CONT'D)

3.2.2.2.- DRY SEPARATORS

THICKNESS=F(COMPRESSION)

DRY SEPARATORS



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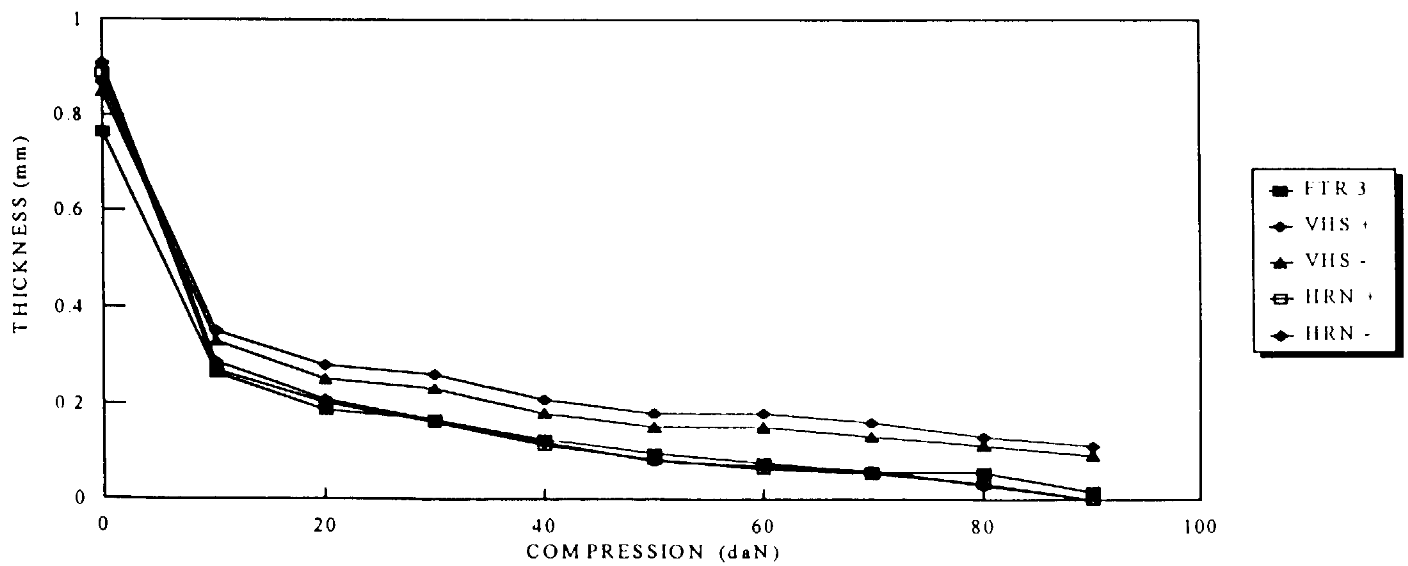
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.2- MECHANICAL CHARACTERISTICS
3.2.2- COMPRESSIBILITY MEASUREMENTS (CONT'D)

3.2.2.3.- WITH KOH ELECTROLYTE

THICKNESS = F(COMPRESSION)
KOH impregnated separators



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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3-SEPARATOR CHARACTERIZATION
3.2- MECHANICAL CHARACTERISTICS
3.2.2.- COMPRESSIBILITY MEASUREMENTS (CONT'D)

3.2.2.3.- WITH KOH ELECTROLYTE (CONT'D)

WE DEDUCT THE COMPRESSIBILITY AT 90 daN :

	COMPRESSIBILITY AT 90 daN	
SEPARATORS	DRY	IMPREGNATED
FTR 3	50,9%	98%
VHS 50+	65,4%	87,3%
VHS 50-	76,1%	89,3%
HRN 42+	81,4%	99%
HRN 42-	88,1%	99,9%

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3.2.3 - CONCLUSION

- THE KOH SEPARATORS CYCLING LEAD TO A SLIGHT DECREASE OF THEIR MECHANICAL RESISTANCE AND AN INCREASE OF THE COMPRESSIBILITY LEVEL.
- BOTH, NEW OR AGED SEPARATORS ARE NOT BRITTLE AND EASY TO HANDLE.

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3.3 - PHYSICO - CHEMICAL MEASUREMENTS

3.3.1 - ELECTROLYTE ABSORPTION

3.3.2 - ELECTROLYTE DIFFUSION

3.3.3 - ELECTROLYTE RETENTION

3.3.4 - CHEMICAL ANALYSIS

3.3.5 - CONCLUSION

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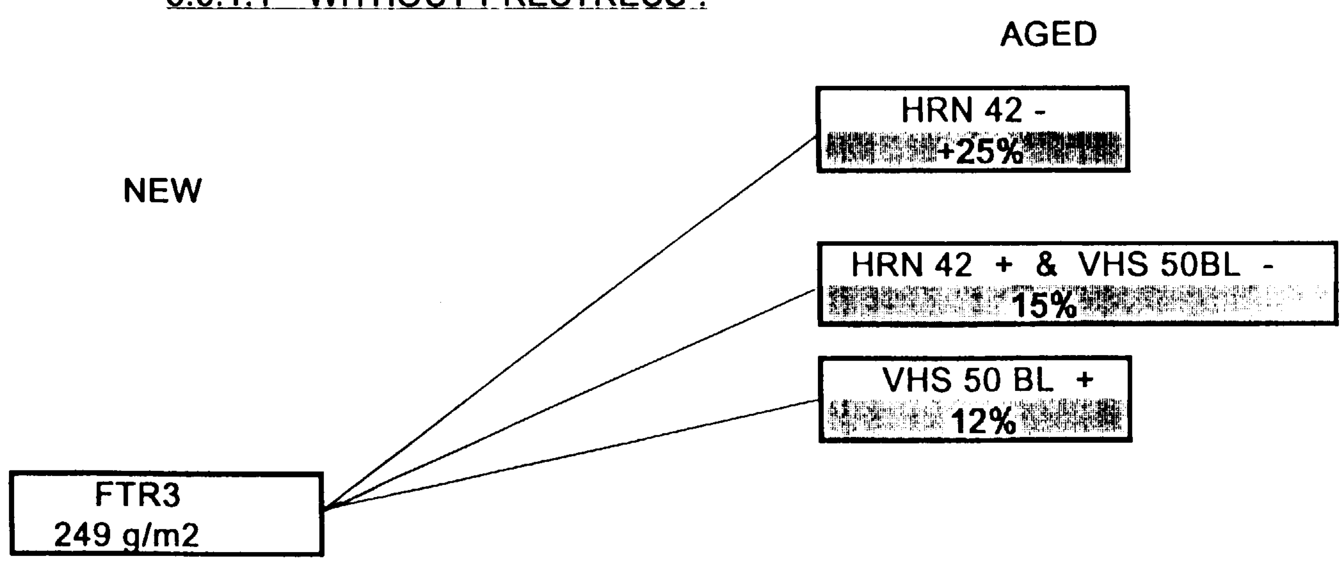
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3 - SEPARATOR CARACTERIZATION
3.3 - PHYSICO-CHEMICALMEASUREMENTS

3.3.1 - ELECTROLYTE ABSORPTION :

3.3.1.1 - WITHOUT PRESTRESS :



ABSORPTION BETTER FOR : HRN 42 / VHS 50 BL / FTR 3
NEGATIVES / POSITIVES SEPARATORS

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

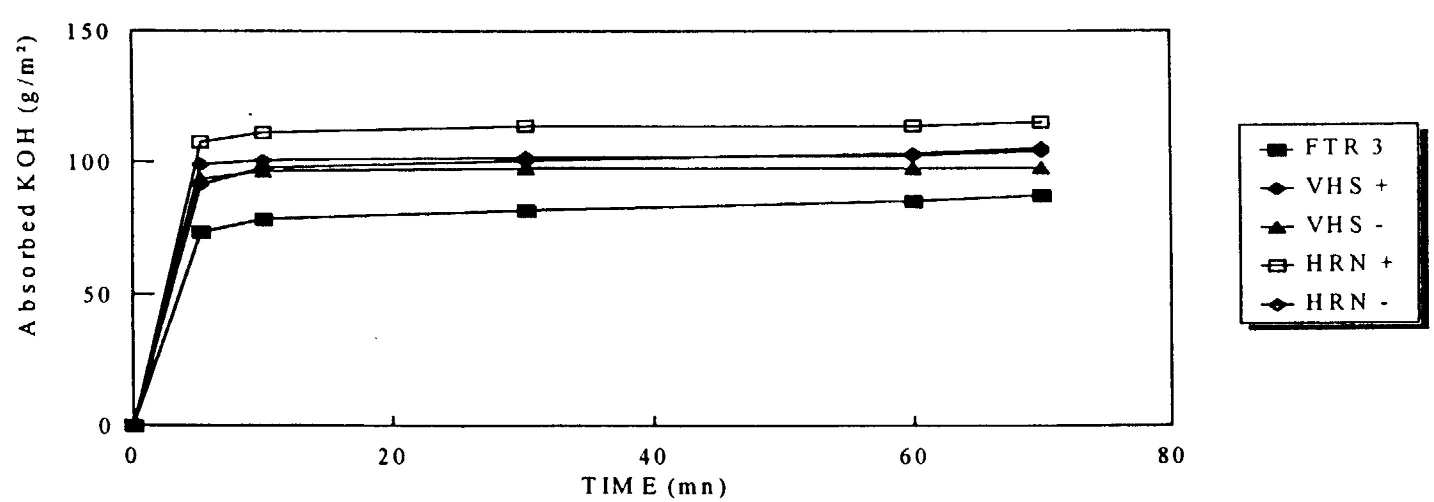
3 - SEPARATOR CARACTERIZATION
3.3.1 - ELECTROLYTE ABSORPTION

3.3.1.2 - WITH PRESTRESS :

One sample : 5 separators (6 sqcm each) stack
Compression strength : 5, 10 and 20 daN

KOH ABSORPTION

P = 20 daN



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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3 - SEPARATOR CARACTERIZATION
3.3.1 - ELECTROLYTE ABSORPTION
3.3.1.2 - WITH PRESTRESS (CONT'D)

AT 70 MN OF ABSORPTION :

	ABSORPTION AT 5 daN		ABSORPTION AT 20 daN	
SEPARATOR	AVERAGE (g/m^2)	INCREASE (%)	AVERAGE (g/m^2)	INCREASE (%)
HRN 42 +	143.2	18	115.5	32
HRN 42 -	141.1	16	104.5	21
VHS 50 +	147.4	21	105.3	20
VHS 50 -	138.1	14	98.2	12
FTR 3	121.6	/	87.4	/

KOH ABSORPTION

LOWER ► HIGHER
NEW ► AGED SEPARATORS
NEGATIVES ► POSITIVES

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

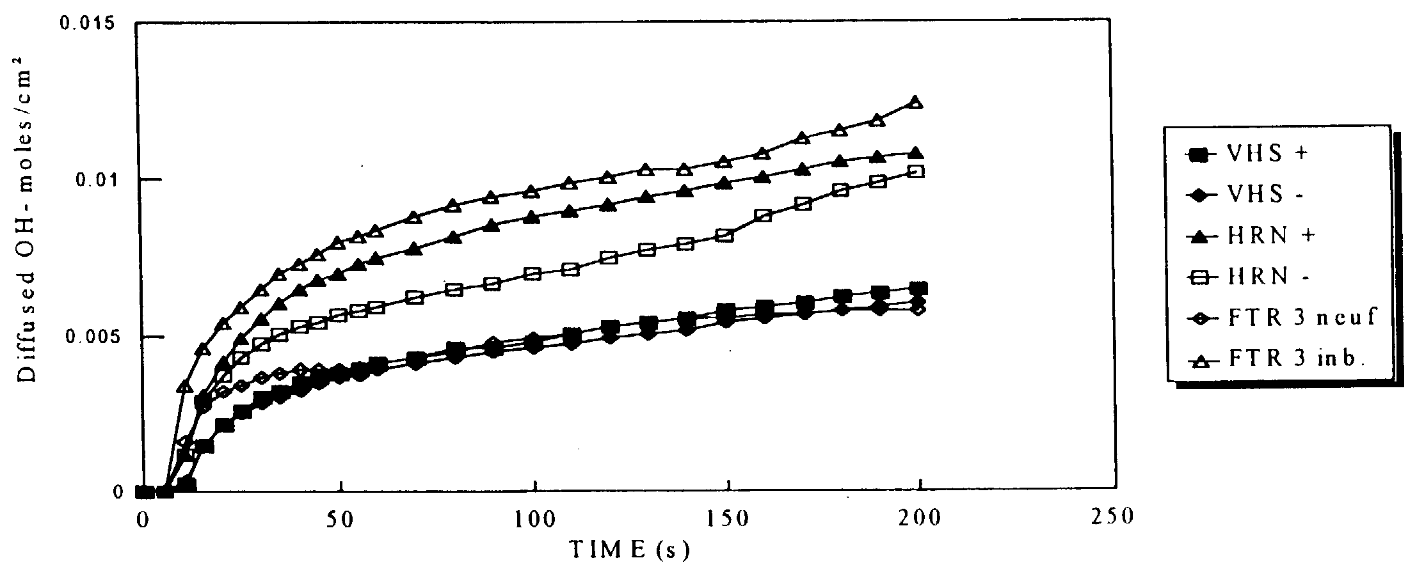
3 - SEPARATOR CARACTERIZATION
3.3.2 - ELECTROLYTE DIFFUSION

Sample surface : 3.14 sqcm

Double compartement : some water on one side, KOH (1.55 %) on the other side.

pH measurement = f(time)

KOH DIFFUSION = F(TIME)



IONIC DIFFUSION : DRY FTR3 (FIBERS NOT REORGANIZED)

IMPREGNATED FTR3 > HRN 42 > VHS 50 BL

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

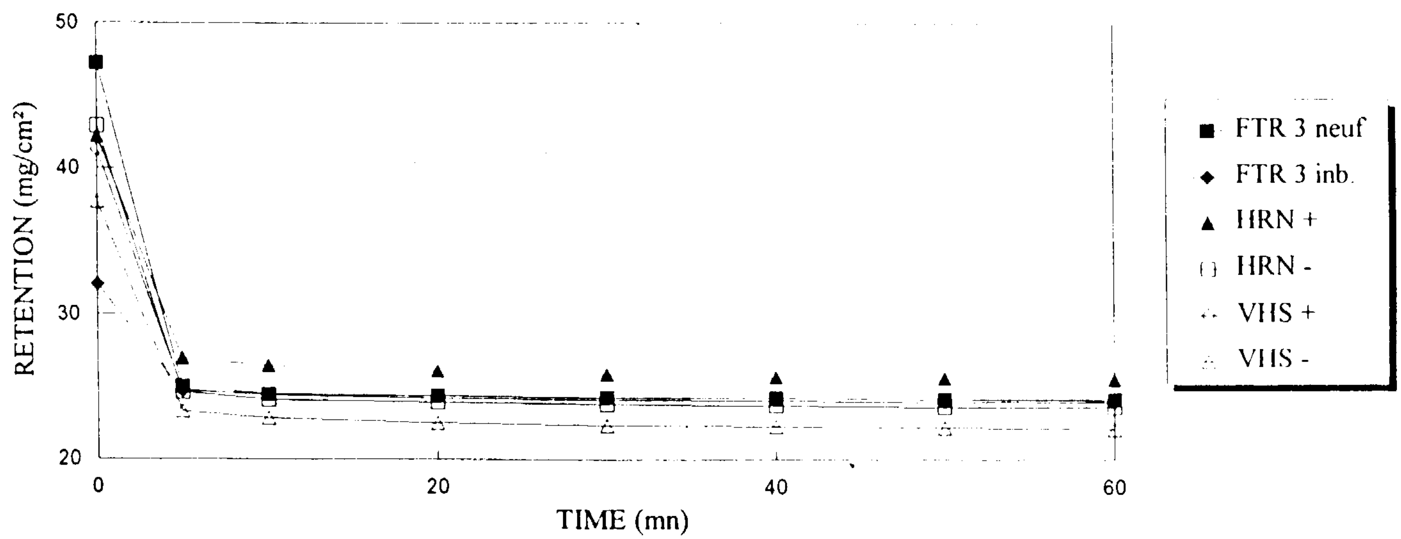
3 - SEPARATOR CARACTERIZATION
3.3.3 - ELECTROLYTE RETENTION

Impregnated sample one night
Gravity effect

3.3.3.1 - WITHOUT COMPRESSION :

RETENTION=F(TIME)

Without compression



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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3 - SEPARATOR CARACTERIZATION
3.3.2 - ELECTROLYTE RETENTION

AFTER ONE HOUR :

SEPARATORS	KOH LOSS (%)	VARIATION (%)
IMPREGNATED FTR 3	74.9	/
HRN 42 +	60.4	-19
HRN 42 -	54.9	-27
VHS 50+	57.9	-23
VHS 50 -	58.4	-22

KOH RETENTION :
AGED > IMPREGNATED FTR3
POSITIVE > NEGATIVE SEPARATOR

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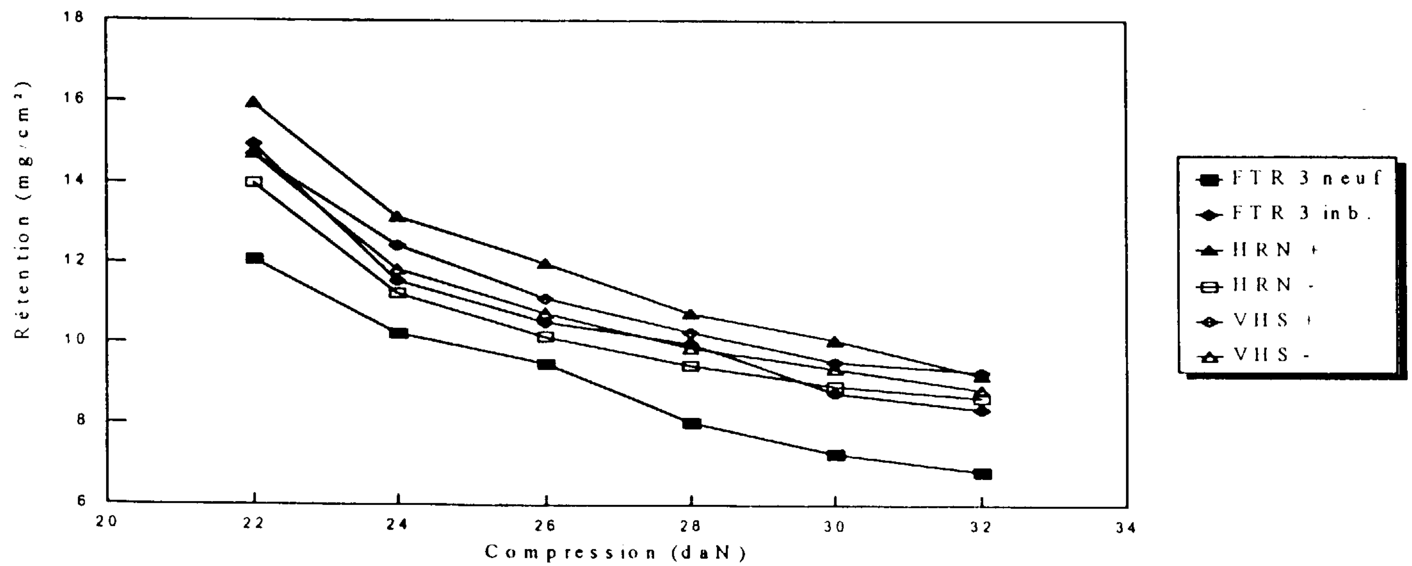
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3 - SEPARATOR CARACTERIZATION
3.3.3 - ELECTROLYTE RETENTION (CONT'D)

3.3.3.2 - WITH COMPRESSION :

RETENTION = F(COMPRESSION)



RETENTION : IMPREGNATED FTR 3 > NEW FTR 3
AGED SEPARATORS > NEW FTR 3

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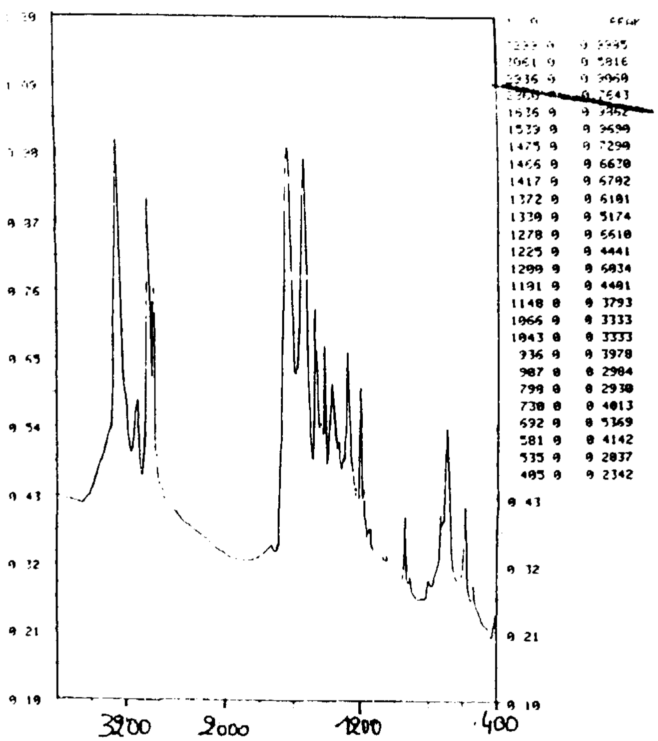
POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

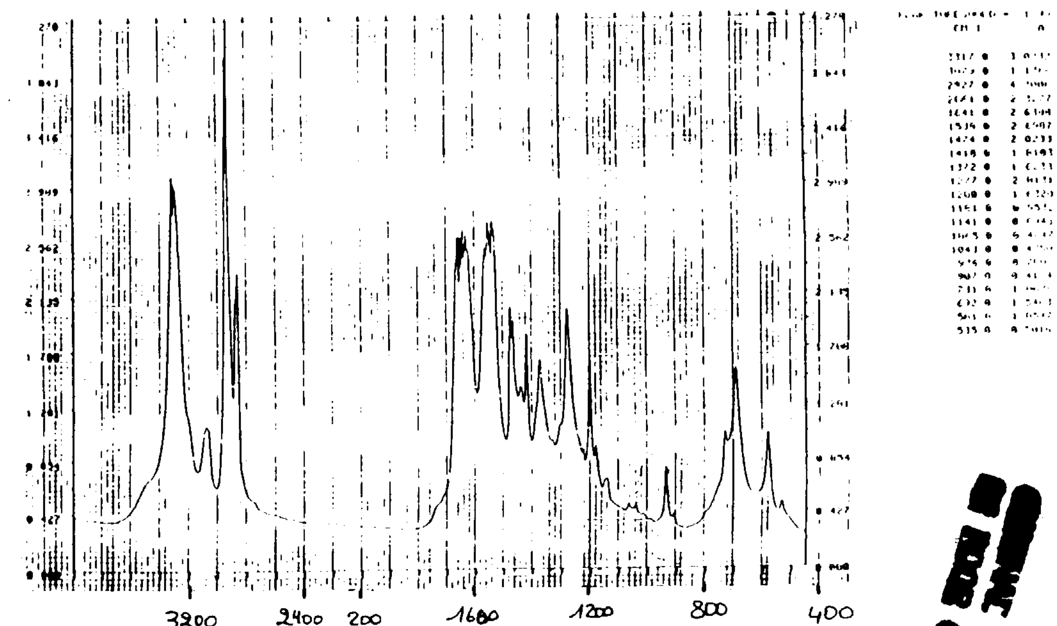
3 - SEPARATOR CARACTERIZATION
3.3.4 - PHYSICO-CHEMICAL MEASUREMENTS
INFRA-RED ANALYSIS

HRN 42 : INFRA-RED SPECTRUM

AGED SEPARATOR (HRN 42 CELL)



NEW SEPARATOR



NO VISIBLE DIFFERENCE

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

3 - SEPARATOR CARACTERIZATION
3.3.5 - CONCLUSION

CYCLING :

KOH ABSORPTION INCREASES WITH OR WITHOUT PRESTRESS.

KOH DIFFUSION DECREASES.

POSITIVE > NEGATIVE FOR : ABSORPTION
DIFFUSION
RETENTION

NO DIFFERENCE IN THE INFRA-RED SPECTRUM.

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

4 - CONCLUSION

SIZE :

→ THICKNESS, SURFACIC DENSITY INCREASE.

MECHANICAL CHARACTERISTICS :

→ EASY TO HANDLE

→ SLIGHT DECREASE IN MECHANICAL RESISTANCE

→ INCREASE IN COMPRESSIBILITY

PHYSICO - CHEMICAL MEASUREMENTS :

→ KOH ABSORPTION, RETENTION INCREASE

→ KOH DIFFUSION DECREASES

→ NO CHANGE IN THE CHEMICAL ANALYSIS

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POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS

4 - CONCLUSION (CONT'D)

- ►CHANGES IN THE SEPARATOR CHARACTERISTICS AFTER CYCLING HAVE BEEN IDENTIFIED.
- ►THIS INCREASES OUR KNOWLEDGE OF THE POLYAMID SEPARATOR BEHAVIOUR IN NiH2 CELLS.
- ►ONLY SLIGHT DIFFERENCES BETWEEN NEW AND AGED SEPARATORS WERE NOTICED.
- ►THIS STRENGTHENS SAFT CHOICE TO USE THIS SEPARATOR IN NiH2 AND NiCd CELLS.